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THE RESOURCES AGENCY

Department of Water Resources

BULLETIN No. 16-65

WEATHER MODIFICATION OPERATIONS IN CALIFORNIA

October 1, 1964–September 30, 1965

AUGUST 1966

HUGO FISHER
Administrator
The Resources Agency

EDMUND G. BROWN
Governor
State of California

WILLIAM E. WARNE
Director
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FOREWORD

In the late 1940's, General Electric Company scientists Irving Langmuir, Vincent Schaefer, and Bernard Vonnegute demonstrated by laboratory and field experiments that certain supercooled clouds which would not naturally yield precipitation can be made to precipitate moisture artificially. These experiments caused great interest in the possibility of increasing rainfall, and many weather modification projects were conducted. Before 1951, such weather modification operations in California were not subject to state regulation. However, the Legislature of 1951, in order to protect the public interest, health, and safety, and to develop and conserve the water resources of California, enacted a law governing weather modification operations within the State (Chapter 1677, Statutes 1951). The statute was incorporated in the Water Code in 1953 as Chapter 4, Division 1, Sections 400 through 415.

The State Water Code Sections governing weather modification projects in California prescribe procedures for licensing contractors, and for initiating and reporting a project. These sections also describe special cases and indicate penalties for violation of the statute. The Department of Water Resources administers the Water Code provisions governing weather modification operations in California.

This bulletin, the tenth in a continuing series, presents a description of weather modification projects and

evaluation techniques in California, according to data in notices of intention, project completion reports, and project evaluation reports submitted to the Department under the Water Code requirements. A list of weather modification licensees is given in Table 1, and the State and Federal provisions governing weather modification operations are included in Appendixes A and B.

William E. Warne, Director
Department of Water Resources
The Resources Agency
State of California

TABLE OF CONTENTS

Page

FOREWORD iii

ACKNOWLEDGMENT viii

ORGANIZATION, DEPARTMENT OF WATER RESOURCES ix

ABSTRACT xi

CHAPTER I. PRECIPITATION 1

CHAPTER II. WEATHER MODIFICATION PROJECTS 5

Santa Clara Cloud-Seeding Program 5

Kern River Watershed Weather Modification Project 7

Upper San Joaquin River Basin Weather Modification Project 7

San Benito County Weather Modification Project 9

Artificial Nucleation Program in the San Gabriel River, Big Tujunga, and Pacoima Drainage Basins 11

Kings River Weather Modification Project . . . 15

Tulare County Weather Modification Project 19

Upper Santa Ana River Watershed Weather Modification Project 23

Northern Sierra Mountains Weather Modification Project 25

Lake Henshaw Basin Weather Modification Project 27

CHAPTER III. SUMMARY OF OPERATIONS 31

TABLES

No.		Page
1	Active Weather Modification Licensees During October 1964 through September 1965	35
2	Summary of Weather Modification Projects in California, October 1, 1964-September 30, 1965	36
3	Summary of Project Operations in California, October 1, 1964-September 30, 1965	37

ILLUSTRATIONS

	Page
Rain Gage at Crabtree Meadow in Upper Kern River Basin	xii
Aerial Snow Depth Marker in Upper San Joaquin River Basin	2
Looking Toward Isabella Reservoir on Kern River	8
Mt. Hooper and Seldon Pass, Upper San Joaquin River Basin	10
Pacoima Dam in San Gabriel Mountains	12
Headwaters of Middle Kings River	14
Dodson Meadow in Kings River Watershed	18
Looking Toward Success Dam on Tule River	20
Stover Mountain. Mountain Meadows Dam	26
Lake Henshaw	28

PLATES

No.		Page
1	Location of Weather Modification Projects, 1964-65	39
2	Weather Modification Operations in California, Days of Cloud Seeding, October 1964-September 1965	41
3	Total Days of Cloud-Seeding Per Month in California, October 1, 1964-September 30, 1965	43
4	Total Hours of Cloud Seeding Per Month From Ground-Based Equipment, October 1, 1964-September 30, 1965	45
5	Total Hours of Cloud Seeding Per Month From Aircraft, October 1, 1964-September 30, 1965	47

APPENDIXES

		Page
A	Statutes Pertaining to Administration of Weather Modification Projects in California	49
B	Federal Regulations Pertaining to Weather Modification	55

ACKNOWLEDGMENTS

The Water Rights Engineering Section wishes to thank the weather modification licensees of California for their cooperation in supplying information on their cloud-seeding projects.

We also wish to thank the Department's Snow Surveys and Water Supply Forecasting Section of the Statewide Operations Office for supplying statewide precipitation data and illustrations of the Kern, Kings, and Upper San Joaquin River Basins; the Graphic Services for supplying the remaining illustrations; and the Reports Administration Technical Support for editorial assistance.

State of California
The Resources Agency
DEPARTMENT OF WATER RESOURCES

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ABSTRACT

During the 1964-65 water year, eight licensees of California conducted 10 cloud-seeding projects. The projects were conducted mainly to increase surface storage for municipal and irrigation uses, for use in recreational facilities, and use in hydroelectric installations. In addition, some projects were conducted to increase ground water storage or for research purposes. Six project target areas were located in central California, three in southern California. One project target area was located in the Northern Sierra Mountains.

A total of 15,239 hours of seeding was logged for ground-based equipment, and 267.1 hours for aircraft. Seven licensees used silver iodide, dispersed from ground-based generators, aircraft, or pyrotechnic fusees used on the ground, as a nucleation agent. In addition to silver iodide, one licensee dispersed 380 pounds of Dry Ice. One licensee used the electric discharge method, in which ions discharged from stainless steel wires act as a nucleation agent.

Rain Gage at Crabtree Meadow in Upper Kern River Basin

CHARTER I. PRECIPITATION

Because weather modification operations in some measure reflect precipitation patterns, statewide precipitation for 1964-65 water year is briefly summarized below. Seasonal and monthly normals (averages) are based on the 30-year period 1931-60.

Statewide precipitation for the 1964-65 season was about 120 percent of normal. The extremes varied from a low of 29 percent of normal at Thermal, in the Whitewater drainage of the Colorado Desert area, to a high of 167 percent of normal at Twin Lakes, in the upper American River drainage. Accumulated inches of precipitation over the 12-months' period contrasted widely from a statewide low of only 0.84 inch at Thermal to a high of 137.43 inches at Board Camp Mountain, near the western ridge of the Trinity River drainage.

Precipitation was generally well above normal over the northern two-thirds of the State. The North Coastal area averaged about 130 percent of normal, Central Coastal--105 percent, Sacramento Valley--130 percent, San Joaquin Valley--110 percent, and the Lahontan area--125 percent. The South Coastal area and the Colorado Desert area received amounts of precipitation slightly below normal, having about a 15 to 20 percent deficiency at the end of the water year.

Precipitation climbed to 150 percent of normal from October through December 1964. In the North Coastal area, slightly less than half of the total rainfall received was

Aerial Snow Depth Marker in Upper San Joaquin River Basin

dumped during the December deluge when some stations had maximum 24-hour totals of about 15 inches and storm totals for six consecutive days of over 50 inches.

Because high pressure systems dominated the weather pattern, the months of January, February, and March were relatively dry. The weather circulation pattern changed temporarily during April as a series of four storms broke through and produced monthly totals of about 200 percent of normal over most of the State. Stations in Southern California reported up to 500 percent of average rainfall for April. The spring months of May and June were predominantly fair with no significant precipitation.

Precipitation during the summer months does not normally have a significant effect on California's water supplies. However, moisture laden clouds swept into California from the southeast during the second week of August bringing unseasonal amounts of precipitation to most areas of the State. Although record and near record August totals were received at inland stations throughout Northern California, the heaviest amounts were recorded in Central Sierra and Cascade watersheds.

CHAPTER II. WEATHER MODIFICATION PROJECTS

Between October 1, 1964, and September 30, 1965, the Department of Water Resources issued 13 weather modification licenses. Eight licensees conducted 10 projects during this period. Information submitted to the Department on the projects varied from minimum data required by the State law to detailed project completion and evaluation reports. These detailed reports, in addition to daily logs, included descriptions of storms, physical features of target area, equipment, and methods of evaluation; and photographs, charts, graphs, maps, and other information of special interest. The following project descriptions are presented according to data in notices of intention, and project completion and evaluation reports submitted to the Department by licensees.

Santa Clara Cloud Seeding Program

Between November 1, 1964, and March 31, 1965, the Weather Modification Company, holder of License No.6, conducted weather modification project operations for the Santa Clara Valley Water Conservation District. This project was conducted in order to regulate precipitation in parts of the County of Santa Clara. Equipment was operated in Santa Clara, San Mateo, Santa Cruz, Monterey, and San Benito Counties. Areas adjacent to the target area which were possibly affected by the project were parts of Alameda, San Mateo, Santa

Cruz, Monterey, San Benito, Merced, Stanislaus, and San Joaquin Counties.

Twenty ground-based propane generators burned a 5% solution of silver iodide chemicals, dispersing silver iodide at a rate of 25 grams per hour per generator. A Beechcraft Bonanza aircraft equipped with a flare generator which burned silver iodide impregnated flares, dispersing silver iodide at a rate of 30 grams per hour, was used for aerial seeding. Because the aircraft was transponder equipped, it was possible to get instrument clearances to fly over the target area. Thus no opportunities for seeding were missed. Changes in the flare generator enabled the burning of two or three flares at the same time, increasing the output of silver iodide crystals. The ground-based generators were operated for 1876.8 hours, and the aircraft for 35.2 hours during 26 flights.

Due to capacity water levels being reached in the reservoirs along the western side of the target area, seeding activities were curtailed. The Santa Clara Valley Water Conservation District requested the Weather Modification Company to terminate seeding in the Stevens Creek Reservoir area begining January 7, 1965. Between February 4, 1965, and March 25, seeding was conducted only in the eastern portions of the target area. Seeding in all portions of the target area, excluding the Stevens Creek area, was resumed on March 26 and carried on until the end of the project. No seeding from aircraft was conducted after January 23, 1965.

In evaluating the project, the Weather Modification

Company used precipitation data from 17 control stations and 25 target area stations. Average normal rainfall, based on the period 1944 to 1954, was calculated for both control and target stations. A comparison of normal average target rainfall and normal average control rainfall indicated a target-control ratio. Multiplying the average seasonal accumulation of precipitation for the control stations by this ratio, an estimate was made of average accumulation in the target area without seeding. Comparing the estimate with the actual average accumulation in the target area, it was found that precipitation increased by 20.49 inches, about 13.4% more than the expected amount. This is equivalent to approximately 776,000 acre-feet.

Kern River Watershed Weather Modification Project

Between October 27, 1964, and April 9, 1965, the Precipitation Control Company of California, holder of License No.12, conducted weather modification project operations for the County of Kern. This project was conducted in order to increase precipitation in the Kern River watershed.

Project equipment included a Cessna 310 aircraft dispersing silver iodide at a rate of approximately 1.5 ounces per hour. The aircraft was operated for 100 hours during 48 flights.

Upper San Joaquin River Basin Weather Modification Project

Between October 27, 1964, and July 17, 1965, North American Weather Consultants of California, holder of License

Looking Toward Isabella Reservoir on Kern River

No.14, conducted weather modification project operations for the Southern California Edison Company. This project was conducted in order to increase precipitation in the upper San Joaquin River Basin. Equipment was operated in the vicinity of Mammoth Pool, Huntington Lake, Shaver Lake, Florence Lake, and Kaiser Pass and adjacent foothill areas in the counties of Fresno and Madera. The target area was the drainage area of the upper San Joaquin River and its tributary streams in the County of Fresno. The basin of the San Joaquin River above Power House No.8 and adjacent foothills were also possibly affected by the project.

Project equipment included 12 ground-based generators emitting silver iodide at the rate of 6.7 grams per hour per generator. The ground generators were operated for 4,612.8 hours.

San Benito County Weather Modification Project

Between January 19, 1965, and April 14, 1965, North American Weather Consultants of California, holder of License No.14, conducted weather modification project operations for San Benito County. This project was conducted in order to increase precipitation in the County. Equipment was operated in the Counties of Monterey and San Benito. The project affected areas only within San Benito County.

Project equipment included 14 ground-based generators emitting silver iodide at the rate of 6.7 grams per hour per generator. The ground generators were operated for 1,522.5

Mt. Hooper and Seldon Pass, Upper San Joaquin River Basin

hours during the project period. Most days of seeding occurred during March and April.

Artificial Nucleation Program in the San Gabriel River, Big Tujunga, and Pacoima Drainage Basins

Between November 9, 1964, and April 12, 1965, the Los Angeles County Flood Control District, holder of License No.18, conducted weather modification project operations on its own behalf. This project was conducted in order to increase precipitation at certain locations in the San Gabriel Mountains. Equipment was operated in areas adjacent to the drainage areas tributary to District-owned dams. The target areas were located in the San Gabriel Mountains and adjacent to the District-owned dams, extending from Pacoima Dam on the west to Thompson Creek Dam on the east. Mountainous areas lying generally northward from the southern foothills of the San Gabriel Mountains between the City of San Fernando and the City of Claremont were possibly affected by the project.

Before initiating operations, the Los Angeles County Flood Control District considered undertaking measures to reduce the possibility of an artificial precipitation increase in areas burned between 1962 and 1964. However, an evaluation by North American Weather Consultants indicated that the effects of seeding would be minor over the burned areas, since these areas lay to the west of the target area.

Project equipment included 16 ground-based propane generators burning a 2% solution of silver iodide and dispersing silver iodide at a rate of 6 grams per hour per generator.

Pacoima Dam in San Gabriel Mountains

The generators were located mainly to the south of the target area. The ground generators were operated for 1,270.8 hours during the project period. The heaviest seeding activity occurred during March and April, when two-thirds of the total seasonal generator-hours were logged.

An evaluation of the project, prepared by North American Weather Consultants, is based on hourly precipitation data obtained during seeded periods, and data from 35 Santa Monica rawinsonde observations made at the same time as seeding operations in the San Gabriel Mountains were conducted. Precipitation data from sixteen rain gages in or near the target area were used. Using rawinsonde data, estimated normal average hourly precipitation amounts for stations in the San Gabriel Mountains were calculated according to quantative formulae. A comparison between estimated and observed precipitation indicated the effect of seeding operations. The evaluation of the project indicated that due to seeding an average precipitation increase of one inch occurred in the central and western portions of the target area. Apparently, no increase occurred in the northeastern portion. Because sufficient hourly precipitation data were not available, evaluations for Pacoima Canyon, in the western tip of the target area, and Big Pines, northeast of the target area, were not completed.

Headwaters of Middle Kings River

Kings River Weather Modification Program

Between October 27, 1964, and April 10, 1965, Atmospherics Incorporated, holder of License No.21, conducted weather modification project operations for the Kings River Conservation District. This project was conducted in order to increase precipitation. Equipment was operated in parts of Fresno, Tulare, and Inyo Counties, and the target area was the Kings River watershed above Pine Flat Reservoir. In addition to the target area, parts of Fresno and Tulare Counties, which include the Kings River and certain tributary streams above Pine Flat Reservoir, were possibly affected by the project.

Project equipment included 30 modified Wells-Fuquay aspirator-type propane ground generators burning a 2% solution of silver iodide in acetone at about 1850° F at a rate of 12 grams of silver iodide per hour per generator. Generator units in the northern portion of the target area were placed in the Wishon Dam-Balch-Trimmer-Piedra area. Those along the southern boundary of the target area were located on Highway 180 and eastward to Cherry Gap, which is slightly over 6,000 feet in elevation. Other generators were placed in the Hills Valley-Badger-Pinehurst area.

Ninety-one silver iodide impregnated pyrotechnic devices similar to road flares were used. Each unit contained 10 grams of silver iodide and burned for 10 minutes. These pyrotechnic devices were an outgrowth of basic research

conducted by the Dr. Vincent Shaefer Research Expedition in Yellowstone during the past four seasons. Although pyrotechnic fusees were used in the Kings River area during the 1963-64 season, their use was expanded during the 1964-65 season. Pyrotechnic devices were ignited only in areas along Highway 180, generally near the cloud base.

A twin-engine Piper Apache aircraft, equipped with de-icing equipment and superchargers for high-altitude all-weather flying, was used in aerial seeding. The aircraft was a valuable supplement to the ground generator network because the placement of generators in locations suitable for complete nuclei coverage is hampered by the presence of wilderness areas within the Kings River watershed.

A total of 21 storm periods, seven in December, occurred in the project area between October 1, 1964, and April 30, 1965. By radar, most of these storms were tracked across the San Joaquin Valley, then into higher mountain areas, where they were seeded. Ground generators were operated during almost all storm periods for a total of 1,964.3 hours, dispersing 23,572 grams of silver iodide. About one-fourth of the total seasonal generator-hours were logged in December, and almost half were logged during March and April. Pyrotechnic fusees used on the ground dispersed 2,630 grams of silver iodide. Pyrotechnic devices were extensively used during January.

The aircraft was operated for 51.5 hours during 54 flights, dispersing 948 grams of silver iodide generally

between cloud base and the -5° C level. Twenty-two flights were made during November and December, and 22 in March and April. During two of the aircraft flights, a total of 380 pounds of Dry Ice pellets (CO_2 crystals) was dispersed at the top of individual cumuliform cloud types. These two flights were made in October and November.

An evaluation by Atmospherics Incorporated stated that it was difficult to separate effects of ground-generator operations from those of aircraft seeding. However, in a number of cases aircraft seeding appeared to trigger precipitation from cumulus formations in which no precipitation was visible at initial time of seeding. Ground generators were usually not operated in such cases. Thus, the effects of aircraft seeding were more clearly defined.

According to the evaluation, a statistical analysis of 1964-65 stream flow figures as given by the U.S. Geological Survey indicates no apparent precipitation increase due to cloud seeding. The Merced River measured at Pohono Bridge and the Kern River measured at Kernville together with #3 Canal were used as control streams. Due to thousand-year flood conditions on the Merced River, water topping the Pohono Bridge by three feet, and cloud seeding activities in the Kern River watershed, the evaluation is no longer considered valid.

Evaluations were made each year of the eleven-year period (1955-1965) of the weather modification program.

Dodson Meadow in Kings River Watershed

According to these evaluations, cloud seeding produced a total apparent increase of 762,000 acre-feet in Kings River flow. It should be emphasized, however, that because adjacent weather modification projects were conducted on control streams, Atmospherics Incorporated does not consider the evaluations valid since 1964.

A portion of the project comprised basic research under a cost-sharing contract between the National Science Foundation and Atmospherics Incorporated. This research, conducted in the watersheds of the Kern, Tule, Kaweah, Kings, San Joaquin, and Merced Rivers, consists of "Physical Studies of Winter Storm Mechanisms as Related to Cloud Seeding Efforts in the Sierra Range of California". The research effort includes tracking both natural and artificial nuclei, time-lapse and radar photography, air potential recordings, condensation nuclei counts, temperature profiles, ice crystal replication, and wind flow studies. Of primary importance was the tracking of silver iodide plumes emitted from both ground generators and aircraft. Some results of this research were included in "Tracking Silver Iodide Nuclei under Orographic Influence", a paper presented at the 24th National Meeting of the American Meteorological Society in Reno, Nevada, October 18-22, 1965.

Tulare County Weather Modification Project

Between December 2, 1964, and April 11, 1965, Atmospherics Incorporated, holder of License No.21, conducted

Looking Toward Success Dam on Tule River

weather modification project operations for the County of Tulare. This project was conducted in order to increase precipitation in a portion of Tulare County. On the north the project area is bounded by the Kings River drainage between the junction of Cover Road and Highway 180, and Triple Divide Peak; on the east and south, by the Tulare county line; on the west, by Highway 65 to its junction with Highway 198, and an imaginary line north from this point to the junction of Cover Road and Highway 180. Equipment was operated in parts of Fresno, Tulare, Kings, Kern, and Inyo Counties.

Project equipment comprised a twin-engine Piper Apache aircraft. For the 1964-65 season distance measuring equipment was installed in the Piper Apache, making it possible to position the aircraft more accurately. Although seeding capability of the aircraft system includes use of silver iodide, Dry Ice, and organic materials and other agents used primarily for experimental purposes, only silver iodide, dispersed from pyrotechnic seeding devices in the aircraft, was used. A total of 2,650 grams of silver iodide was dispersed.

During the twenty storms which moved through the project area in the 1964-65 season, the aircraft made 62 seeding flights. While most seeding flights were made along north-south tracks beyond the western border of the project area, seeding flights were occasionally made within the project area when suitable cloud conditions were present over high elevation areas of the Kaweah and Tule watersheds. Many flights

were made under instrument flight rules or in storm areas where moderate to severe icing and turbulence were experienced. Seeding flight time totalled 80.4 hours. About 10% of the flight hours were logged during night operations. More than 35% of the total seasonal hours of seeding occurred in December, and about half in March and April. Although the contract period began on November 15, 1964, no seeding operations were conducted in November due to lack of suitable storm situations.

A portion of the project was conducted as a basic research effort funded by the National Science Foundation. This phase of the project was designed to study southern Sierra storm mechanisms and their relation to seeding, and included research on seeding effects, condensation nuclei, freezing nuclei, temperature profiles, low-level wind profiles, ice crystal types, and the evaluation of radar data and use of time-lapse photographs. Sixteen research flights were made concerning the watersheds of the Merced, San Joaquin, Kings, Kaweah, Tule, Kern, and Owens Rivers. For one of the phases of the research program, the investigation of downwind distribution of artificial and natural ice nuclei in snow and water, the Southern California Edison Company, the Department of Water and Power of the City of Los Angeles, and the U.S. Geological Survey aided Atmospherics Incorporated in the procurement of samples from both sides of the Sierra Range.

According to a project evaluation by Atmospherics

Incorporated, comparisons of percent of normal precipitation for target and control stations for the 1964-65 season indicate a precipitation increase of 14.8% within the project area. Stream flow comparisons and physical studies of storms as related to seeding efforts were also used in evaluating project results. Physical studies included tracking silver iodide plumes emitted from aircraft, reduction of radar data, time-lapse photography of specific cloud types, measurement of condensation nuclei, and studies of effects produced by seeding, and of temperature profiles of clouds during seeded and non-seeded periods.

Upper Santa Ana River Watershed Weather Modification Project

Between November 9, 1964, and April 9, 1965, the San Bernardino Valley Municipal Water District, holder of License No.22, conducted weather modification project operations on its own behalf. This project was conducted in order to increase precipitation in the upper Santa Ana River watershed. The target area approximately comprises the portion of the upper Santa Ana River watershed within San Bernardino County. The target area contains about 576,000 acres, and approximately 80% of this area lies within the San Bernardino National Forest.

About half of the target area is over 3,000 feet in elevation. The northern portion of the area, bounded by the San Bernardino mountains, reaches elevations of more than 5,000 feet. The southwest corner of the target area has

an elevation of less than 1,000 feet. Most of the eastern portion of the target area lies above the 3,000 foot level, containing areas more than 8,000 feet in elevation. The Santa Ana River and its tributaries, Mill Creek and City Creek, lie in the eastern portion of the target area.

Equipment was operated in Los Angeles County, Orange County, the southern portion of San Bernardino County, and the western portion of Riverside County. No effect on any area outside the target area was forseen. Project equipment included 20 ground-based generators constructed by district personnel. These units burned a solution of silver iodide in acetone at 1800° F and contained two 100-pound propane tanks with fuel for about 40 hours of seeding.

Due to the corrosive effect of silver iodide solution, steel and iron generator parts have a life of only one season. Therefore, stainless steel and brass were used for generator parts which came in contact with the solution, eliminating failure due to corrosion. By injecting the silver iodide into the burning chamber of the generator under pressure (5 pounds per square inch), the problem of clogging in the mixing nozzle was nearly eliminated, and it became possible to use a more concentrated silver iodide solution. Each generator was equipped with a pressure regulator for the fuel and a flow meter for the chemical solution, allowing adjustments which permitted the operator to regulate the output of the generator and to control the size of the silver iodide crystals.

The generators dispersed silver iodide at a rate of 21 grams per hour per generator. Generators were mainly located within the target area and to the southwest of the target area. The ground generators were operated for 2,366.7 hours during the project period. About half of the total seasonal generator-hours were logged during November and December, and approximately 40% during March and April.

No statistical analysis of the project was made. However, according to a project evaluation by the San Bernardino Valley Municipal Water District, an estimated average precipitation increase of 10% occurred, increasing runoff in the Santa Ana River watershed by approximately 72,000 acre-feet. Lake Gregory, Lake Arrowhead, Green Valley Lake, and Big Bear Lake, all located in the San Bernardino National Forest, received benefits from the seeding program.

Northern Sierra Mountains Weather Modification Project

Between November 21, 1964, and May 21, 1965, the Pacific Gas and Electric Company, holder of License No. 23, conducted weather modification project operations on its own behalf. This project was conducted in order to increase high-level snow pack and subsequent dry-season runoff, and to gather information on the effectiveness of cloud seeding. Equipment was operated in Plumas, Lassen, and Tehama Counties. The target area was the drainage basin of Lake Almanor, Butt Valley Reservoir, and Mountain Meadows Reservoir in the Northern Sierra Nevada Mountains. Areas in the counties of Plumas, Lassen, Shasta, and Tehama were also

Stover Mountain

Mountain Meadows Dam

possibly affected by the project.

Project equipment included six high-elevation, radio-controlled generators which burned a solution of acetone, sodium iodide, and silver iodide. Three generators were located in the southern portion of the target area, two southwest of the target area, and one at Stover Mountain in the western portion of the target area. These ground generators were operated for 1,248.5 hours, releasing 107,372 grams of silver iodide at a rate of 86 grams per hour for all generators combined. About 44% of the total seasonal generator-hours were logged in November and December, and nearly 45% in March and April. No seeding operations were conducted during January.

Lake Henshaw Basin Weather Modification Project

Between August 3 and September 30, 1965, Vista Irrigation District, holder of License No. 27, conducted weather modification project operations on its own behalf. This project represents the beginning of a three-year experimental effort to increase precipitation in Lake Henshaw basin. Equipment was operated in the area adjacent to Henshaw Dam in San Diego County. An area adjacent to the target area which was possibly affected by the project was Warner Ranch in the County.

The electric discharge method was used for the project. Project equipment comprised a transformer which produced a 20 to 50 kilovolt direct current of 1 to 20 milliamperes, overcharging from two thin parallel stainless

Lake Henshaw

steel wires approximately one mile in length. A corona-effect discharge of ions which acted as a nucleation agent was produced. The electric discharge unit was operated for a total of 376 hours during the 1964-65 season. Operation of the unit was attempted on August 3 and 10, but was unsuccessful due to defects in power supply. Actual project operations began on August 12. The unit was operated daily for the entire month of September. Originally, it was to operate only during daylight hours. However, experimentation demonstrated the feasibility of continuous operation of the unit, weather and other conditions permitting.

No appreciable rainfall was recorded during the period the unit was operated.

CHAPTER III. SUMMARY OF OPERATIONS

During the 1964-65 season, eight licensees conducted 10 projects. All 10 of the weather modification projects were conducted to increase surface storage in reservoirs. The purpose of the Santa Clara Cloud-Seeding Program and the San Benito County Weather Modification Project was to increase ground water storage as well as surface storage. In addition to increasing surface storage for municipal use and irrigation, the Upper Santa Ana Watershed Weather Modification Project also benefitted recreational facilities within the San Bernardino National Forest. The Kings River Weather Modification Project, the Tulare County Weather Modification Project, and the Lake Henshaw Basin Weather Modification Project, although conducted to increase surface storage in reservoirs, included research efforts as well. Two weather modification projects were conducted in order to increase runoff upstream from hydroelectric installations. These projects were the Upper San Joaquin River Basin Weather Modification Project and the Northern Sierra Mountains Weather Modification Project.

Most of the 10 weather modification projects conducted during the 1964-65 season had target areas located in central or southern California. Six project target areas were located in central California and three in southern California. One project target area, that of the Northern Sierra Mountains Weather Modification Project, was located in northern California. Locations of weather modification

projects in California are shown on Plate 1.

The period of most extensive weather modification operations comprised the months October through April. However, one licensee, North American Weather Consultants of California, extended generator operations of its Upper San Joaquin River Basin Weather Modification Project through May, June, and July. In addition, Vista Irrigation District conducted operations for its Lake Henshaw Basin Weather Modification Project only during August and September. Some weather modification operations thus occurred during every month of the 1964-65 season. Days of cloud seeding for each project are shown in calendar form on Plate 2.

The heaviest seeding activity according to monthly totals of days of seeding, excluding August and September, took place in November and December. There were 19 days of seeding in November, and 25 in December. Totals of over 10 days of seeding were recorded for January, March, and April, but October and February had 3 and 6 days, respectively. From April to July, monthly totals gradually declined from 13 to 2, respectively. Although 17 days of seeding occurred in August and 30 in September, these monthly totals reflect operations of only one licensee, Vista Irrigation District.

A total of 151 days of seeding occurred during the 1964-65 season. Seeding from ground-based equipment occurred on all recorded days of seeding. Of the total, 51 days of seeding from both ground-based equipment and aircraft occurred, and for 100 days only ground-based equip-

ment was operated. Total days of cloud seeding per month, together with monthly totals for ground-based equipment alone, and ground-based equipment and aircraft are shown in Plate 3.

A total of 15,239 hours of seeding from ground-based equipment occurred during the 1964-65 season. 376 hours were logged during Vista Irrigation District's Lake Henshaw Basin Weather Modification Project, in which the electric discharge method was used. Ground-based equipment used by other licensees comprised generators dispersing silver iodide.

Seeding from ground-based equipment occurred during every month of the 1964-65 season. The heaviest seeding from ground-based equipment according to monthly totals of hours of seeding occurred during December, March, and April. There were 3,487 hours of seeding in December, 3,020 in March, and 3,616 in April. Substantial monthly totals of hours of seeding were logged in November, January, and February, when ground-based equipment was operated for 1,894 hours, 1,435 hours, and 808 hours, respectively. In all other months, less than 500 hours per month of seeding from ground-based equipment occurred. Total hours of cloud-seeding per month from ground-based equipment are shown in Plate 4.

A total of 267.1 hours of seeding from aircraft was logged during the 1964-65 season. Seeding from aircraft occurred in the months October through April. The heaviest seeding from aircraft according to monthly totals of hours of seeding occurred during December, when 92.5 hours were logged. October and February had totals of less than 10

hours each. All other months in which seeding from aircraft occurred had totals of 50.4 to 26.2 hours. Total hours of cloud-seeding per month from aircraft are shown in Plate 5.

Seven licensees used silver iodide, dispersed from ground-based generators, aircraft, or pyrotechnic fusees used on the ground, as a nucleation agent. In addition to silver iodide, one of these licensees, Atmospherics Incorporated, dispersed 380 pounds of Dry Ice (CO_2 crystals) during its Kings River Weather Modification Project. In contrast, one licensee, Vista Irrigation District, used the electric discharge method, in which ions discharged from stainless steel wires act as a nucleation agent.

Weather modification projects are summarized in Table 2, and weather modification project operations are summarized in Table 3.

TABLE 1

ACTIVE WEATHER MODIFICATION LICENSES
DURING OCTOBER 1964, THROUGH SEPTEMBER 1965

License Number	Licensee
1	North American Weather Consultants Santa Barbara Municipal Airport Goleta, California 93017
5	Water Resources Development Corporation 460 South Broadway Denver, Colorado 80209
6	Weather Modification Company San Jose Municipal Airport San Jose, California 95110
12	Precipitation Control Company of California 105 Pierce Street Taft, California 93268
14	North American Weather Consultants of California Santa Barbara Municipal Airport Goleta, California 93017
18	Los Angeles County Flood Control District 2250 Alcazar Street Los Angeles, California 90033
21	Atmospherics Incorporated 3233 Mayfair Drive Fresno, California 93703
22	San Bernardino Valley Municipal Water District 355 North D Street P. O. Box 1144 San Bernardino, California 92402
23	Pacific Gas and Electric Company 245 Market Street San Francisco, California 94106
24	International Weather Control, Inc. 40 West First Street Suite 104 Reno, Nevada
25	K. R. C. Service Corporation 2956 C Street San Diego, California 92102
26	Santa Clara Valley Water Conservation District 15420 Almaden Road San Jose, California 95118
27	Vista Irrigation District P. O. Box 1088 Vista, California 92083

TABLE 2

SUMMARY OF WEATHER MODIFICATION PROJECTS IN CALIFORNIA
OCTOBER 1, 1964 - SEPTEMBER 30, 1965

Project number[a]	Licensee	Client	Target area	Period of operation	Purpose
6-65-1	Weather Modification Company	Santa Clara Valley Water Conservation District	Santa Clara County	Nov. 1, 1964 Mar. 31, 1965	Precipitation increase for surface and ground water storage.
12-65-1	Precipitation Control Company of California	Kern County	Upper Kern River Watershed	Oct. 27, 1964 Apr. 9, 1965	Precipitation increase for surface storage.
14-65-1	North American Weather Consultants of California	Southern California Edison Company	Upper San Joaquin River Basin	Oct. 27, 1964 July 17, 1965	Precipitation increase for storage in hydroelectric installations.
14-65-2	North American Weather Consultants of California	County of San Benito	San Benito County	Jan. 19, 1965 Apr. 14, 1965	Precipitation increase for surface and ground water storage.
18-65-1	Los Angeles County Flood Control District	Los Angeles County Flood Control District	Drainage areas tributary to District's reservoirs	Nov. 9, 1964 Apr. 12, 1965	Precipitation increase for surface storage.
21-65-1	Atmospherics Incorporated	Kings River Conservation District	Kings River Watershed above Pine Flat Dam	Oct. 27, 1964 Apr. 10, 1965	Precipitation increase for surface storage.
21-65-2	Atmospherics Incorporated	County of Tulare	Tulare County	Dec. 2, 1964 Apr. 11, 1965	Precipitation increase for surface storage and research.
22-65-1	San Bernardino Valley Municipal Water District	San Bernardino Valley Municipal Water District	Upper Santa Ana River Watershed	Nov. 9, 1964 Apr. 9, 1965	Precipitation increase for surface storage and recreation.
23-65-1	Pacific Gas and Electric Company	Pacific Gas and Electric Company	Watersheds of Mountain Meadows and Butt Valley Reservoirs and Lake Almanor	Nov. 21, 1964 May 21, 1965	Precipitation increase for storage in hydroelectric installations.
27-65-1	Vista Irrigation District	Vista Irrigation District	Lake Henshaw Watershed, San Diego County	Aug. 3, 1965 Sept. 30, 1965	Precipitation increase for surface storage and research.

[a] First number indicates license number; second - the water year; third - numerical sequence of projects undertaken by a licensee.

TABLE 3

SUMMARY OF PROJECT OPERATIONS IN CALIFORNIA
OCTOBER 1, 1964 - SEPTEMBER 30, 1965

Project number[a]	Licensee	Number of generators	Rate of use of silver iodide in grams per hour per generator		Total amount of silver iodide dispersed, in grams		Total generator hours	
			Ground generators	Aircraft	Ground generators	Aircraft	Ground generators	Aircraft
6-65-1	Weather Modification Company	20	25.0	30	---	---	1,876.8	35.2
12-65-1	Precipitation Control Company of California	--	----	42.5	---	---	---	100.0
14-65-1	North American Weather Consultants of California	12	6.7	----	---	---	4,612.8	----
14-65-2	North American Weather Consultants of California	14	6.7	----	---	---	1,522.5	----
18-65-1	Los Angeles County Flood Control District	16	6.0	----	---	---	1,270.8	----
21-65-1	Atmospherics Incorporated	30	12.0	----	23,572[b]	948[c]	1,964.3	51.5
21-65-2	Atmospherics Incorporated	--	----	----	---	2,650	---	80.4
22-65-1	San Bernardino Valley Municipal Water District	20	21.0	----	---	---	2,366.7	----
23-65-1	Pacific Gas and Electric Company	6	14.3	----	107,372	---	1,248.5	----
27-65-1[d]	Vista Irrigation District	--	----	----	---	---	---	----

(a) - First number indicates license number; second - the water year; third - numerical sequence of projects undertaken by a licensee.
(b) - In addition, the licensee dispersed 2,630 grams of silver iodide from pyrotechnic devices used on the ground.
(c) - The licensee also dispersed 380 pounds of dry ice (CO_2 crystals).
(d) - The licensee used electric discharge method. 50,000 volts of electricity were discharged for 376 hours.

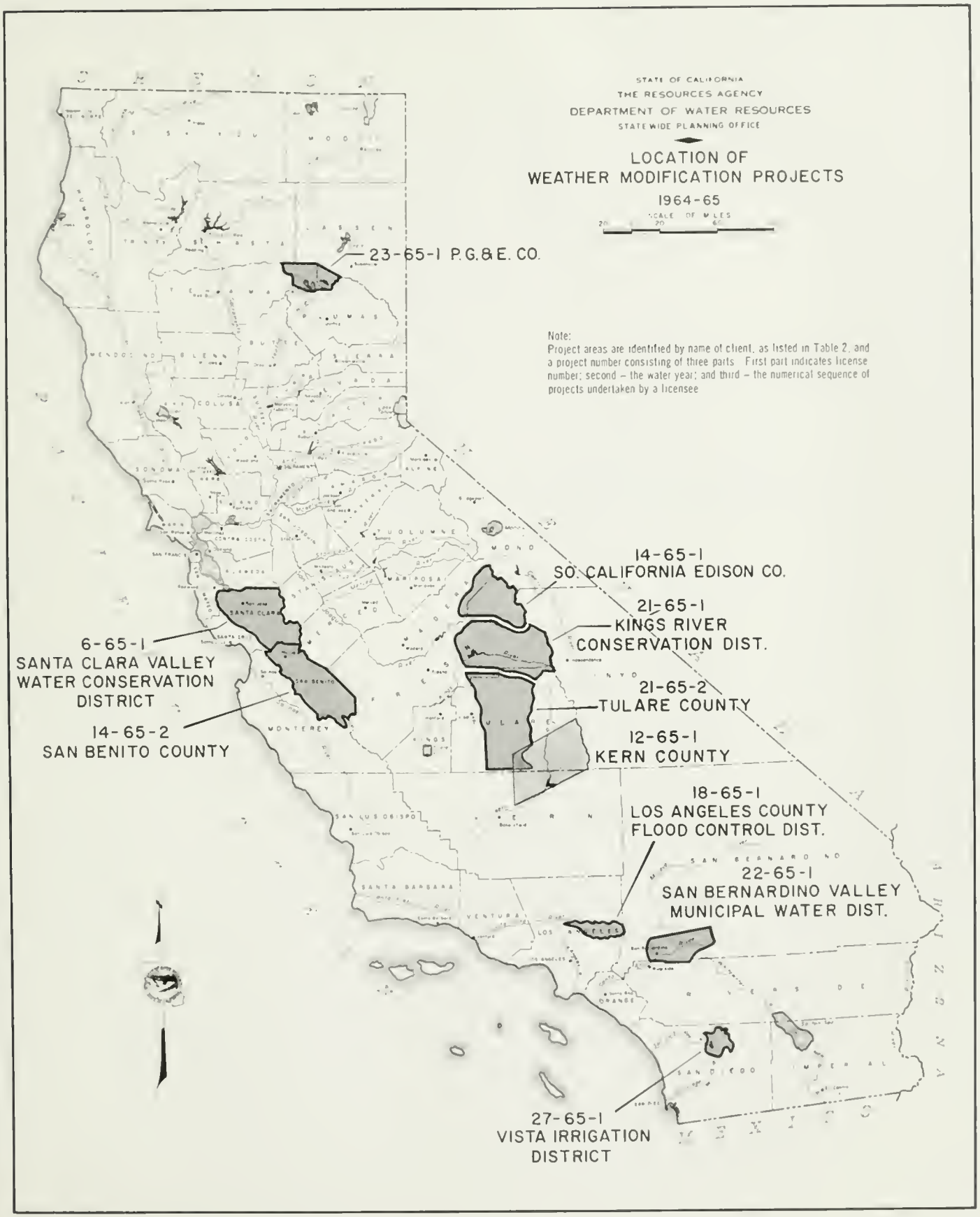
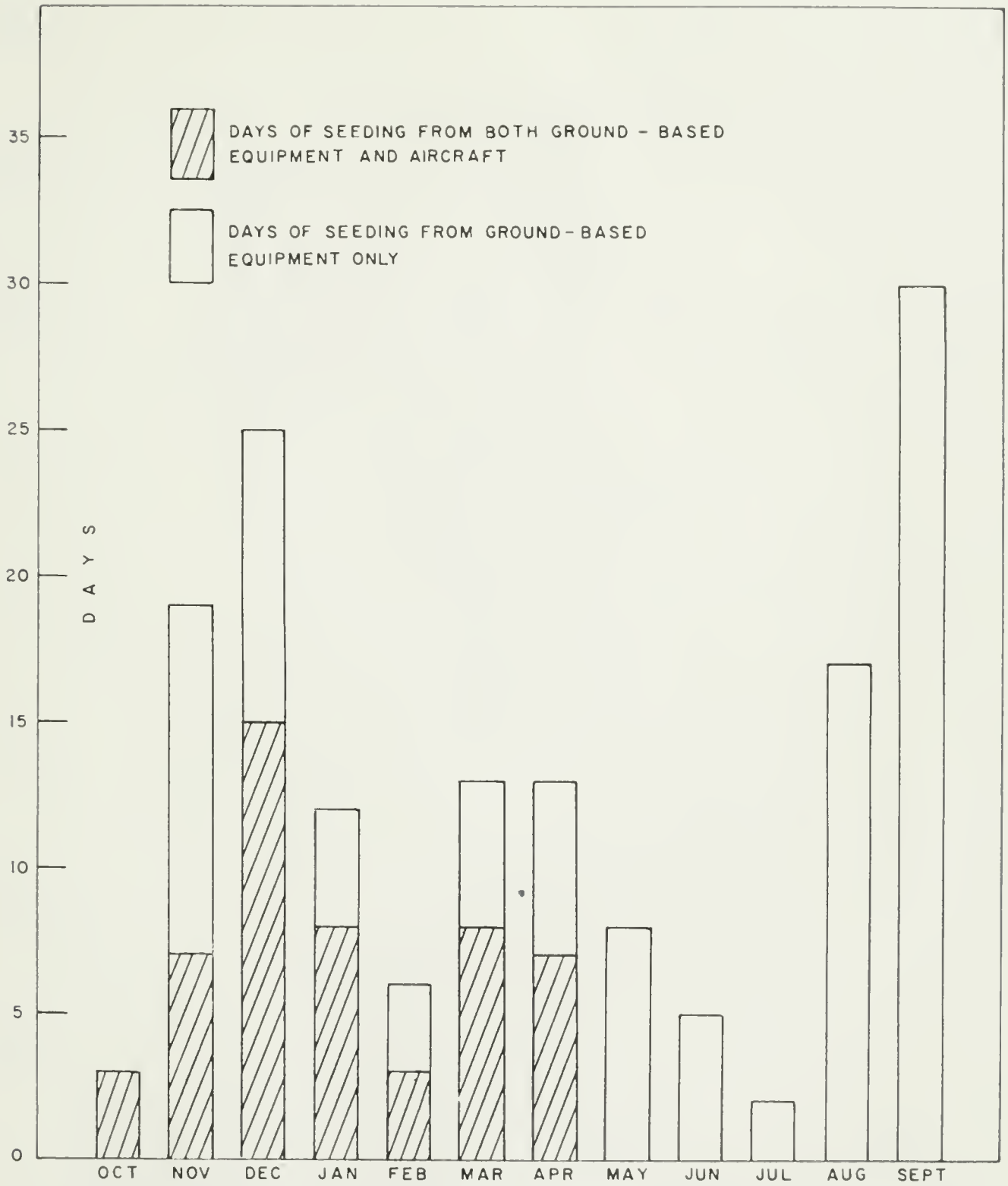
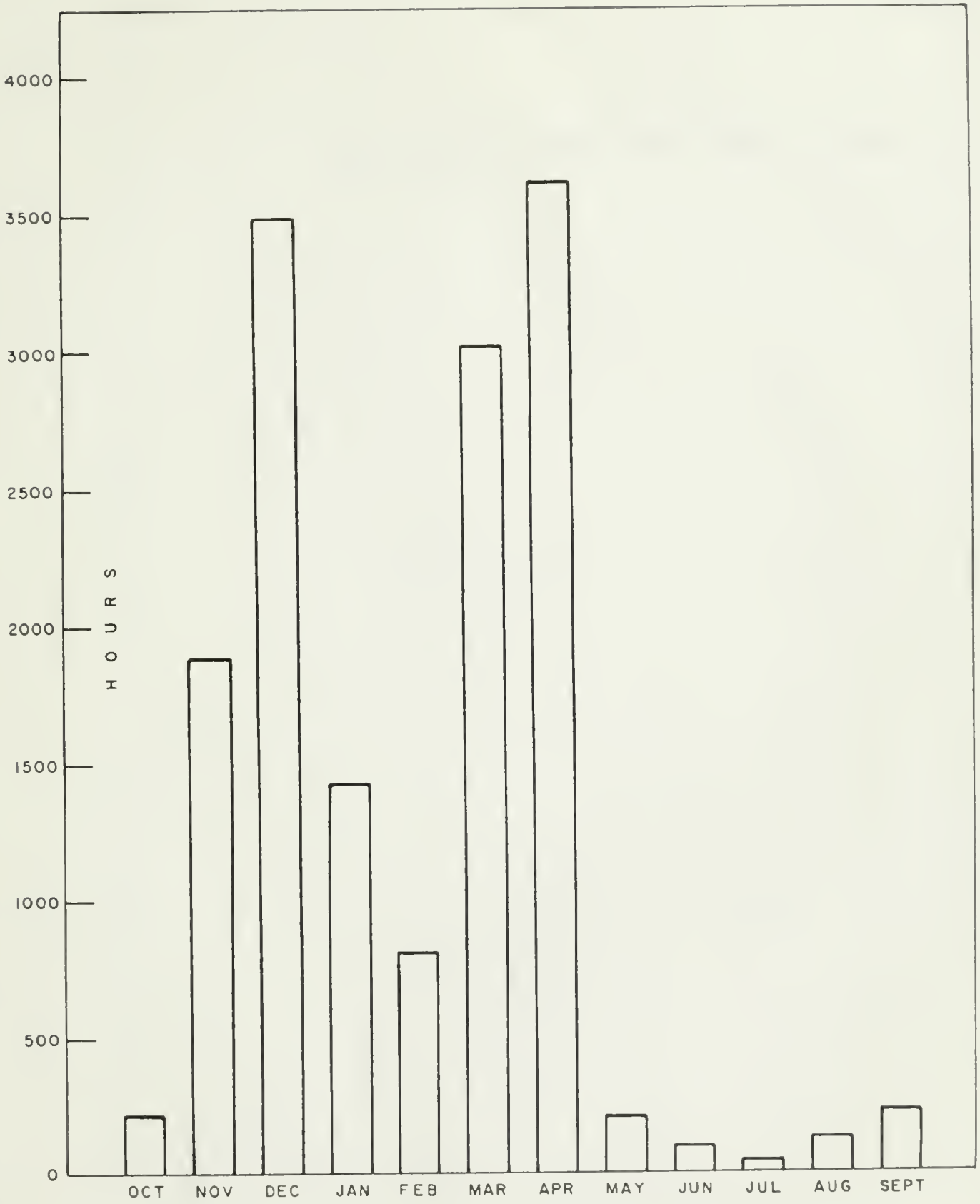

STATE OF CALIFORNIA
THE RESOURCES AGENCY
DEPARTMENT OF WATER RESOURCES
STATE WIDE PLANNING OFFICE
LOCATION OF
WEATHER MODIFICATION PROJECTS
1964-65
SCALE OF MILES
Note:
Project areas are identified by name of client, as listed in Table 2, and a project number consisting of three parts First part indicates license number; second – the water year; and third – the numerical sequence of projects undertaken by a licensee
23-65-1 P.G.&E. CO.
14-65-1
SO. CALIFORNIA EDISON CO.
21-65-1
KINGS RIVER
CONSERVATION DIST.
21-65-2
TULARE COUNTY
12-65-1
KERN COUNTY
6-65-1
SANTA CLARA VALLEY
WATER CONSERVATION
DISTRICT
14-65-2
SAN BENITO COUNTY
18-65-1
LOS ANGELES COUNTY
FLOOD CONTROL DIST.
22-65-1
SAN BERNARDINO VALLEY
MUNICIPAL WATER DIST.
27-65-1
VISTA IRRIGATION
DISTRICT

Plate 2 is bound at the end of the volume.



TOTAL DAYS OF CLOUD-SEEDING PER MONTH IN CALIFORNIA
OCTOBER 1, 1964 – SEPTEMBER 30, 1965

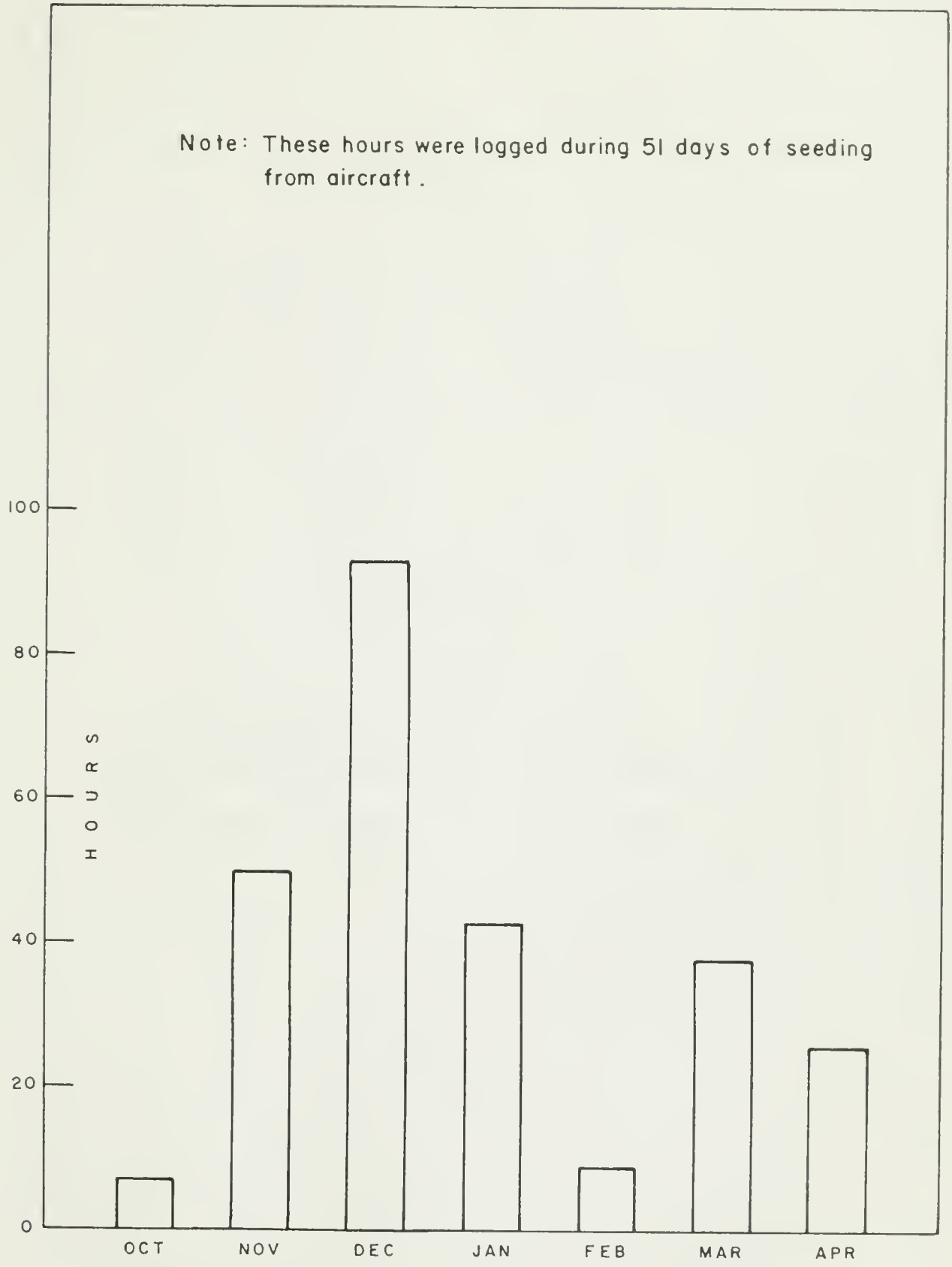
Note: A total of 151 days of seeding occured during the 1964 – 65 season.



TOTAL HOURS OF CLOUD-SEEDING PER MONTH FROM GROUND-BASED EQUIPMENT

OCTOBER 1, 1964 – SEPTEMBER 30, 1965

Note: These hours were logged during 151 days of seeding from ground-based equipment



TOTAL HOURS OF CLOUD - SEEDING PER MONTH FROM AIRCRAFT ONLY

OCTOBER 1, 1964 - SEPTEMBER 30, 1965

APPENDIX A

STATUTES PERTAINING TO ADMINISTRATION OF WEATHER MODIFICATION PROJECTS IN CALIFORNIA

(Sections 400-415, Chapter 4, Division 1, Water Code)

CHAPTER 4. REGULATION OF RAIN-MAKING AND RAIN-PREVENTION

(Chapter 4 added by Statutes of 1953, Chapter 139, as part of codification)

400. The public interest, health, safety, welfare, and necessity require that scientific experimentation in the field of artificial nucleation, and that scientific efforts to develop, increase, and regulate natural precipitation be encouraged, and that means be provided for the regulation and control of interference by artificial means with natural precipitation of rain, snow, moisture, or water in any form contained in the atmosphere, within the State, in order to develop, conserve, and protect the natural water resources of the State and to safeguard life and property.

401. As used in this chapter:

(a) "Department" means the Department of Water Resources.

(b) "Person" means any person, firm, association, organization, partnership, company, corporation, private or public, county, city, city and county, district, or other public agency.

(As amended by Stats. 1959, Ch. 1269)

402. No person, without first securing a license from the department, shall cause or attempt to cause condensation or precipitation of rain, snow, moisture, or water in any form contained in the atmosphere, or shall prevent or attempt to prevent by artificial means the natural condensation or precipitation of atmosphere.

403. Any person desiring to do any of the acts specified in Section 402 may file with the department an application in writing for a license. Each application shall be accompanied by a filing fee fixed by the department with the approval of the Department of General Services but not to exceed fifty dollars ($50) and shall be on a form to be supplied for such purpose by the department.

(As amended by Stats. 1965, Ch. 371)

404. Every application shall set forth all of the following:

(a) The name and post-office address of the applicant.

(b) The previous education, experience, and qualifications of the applicant, or, if the applicant is other than an individual, the previous education, experience, and qualifications of the persons who will be in control of and charged with the operations of the applicant.

(c) A general description of the operations which the applicant intends to conduct and the method and type of equipment that the applicant proposes to use.

(d) Such other pertinent information as the department may require.

405. Upon the filing of the application upon a form supplied by the department and containing the information prescribed by this chapter and accompanied by the required filing fee the department shall issue a license to the applicant entitling the applicant to conduct the operations described in the application for the calendar year for which the license is issued, unless the license is sooner revoked or suspended.

406. A license may be renewed annually upon application to the department, accompanied by a renewal fee fixed by the department with the approval of the Department of General Services but not to exceed twenty-five dollars ($25), on or before the last day of January of the calendar year for which the license is renewed.

(As amended by Stats. 1965, Ch. 371)

407. Prior to undertaking any operation authorized by the license the licensee shall file with the department and cause to be published a notice of intention. The licensee shall then confine his activities for that operation substantially within the time and area limits set forth in the notice of intention.

408. The notice of intention shall set forth all of the following:

(a) The name and address of the licensee.

(b) The nature and object of the intended operation and the person or persons on whose behalf it is to be conducted.

(c) The area in which and the approximate time during which the operation will be conducted.

(d) The area which will be affected by the operation as near as the same may be determined in advance.

409. The licensee shall cause the notice of intention to be published pursuant to Section 6063* of the Government Code in a newspaper having a general circulation and published within any county wherein the operation is to be conducted and in which the affected area is located, or, if the operation is to be conducted in more than one county or if the affected area is located in more than one county or is located in a county other than the one in which the operation is to be conducted, then such notice shall be published in like manner in a newspaper having a general circulation and published within each of such counties. In case there is no newspaper published within the appropriate county, publication shall be made in a newspaper having a general circulation within the county.

(As amended by Stats. 1955, Ch. 482, and by Stats. 1957, Ch. 448)

410. Proof of publication shall be filed by the licensee with the department within 15 days from the date of the last publication of the notice. Proof of publication shall be by copy of the notice as published attached to and made a part of the affidavit of the publisher or foreman of the newspaper publishing the notice.

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* A copy of Government Code Section 6063 follows Section 415 of the Water Code in this appendix.

411. Every licensee shall keep and maintain a record of all operations conducted by him pursuant to his license showing the method employed, the type of equipment used, the times and places of operation of the equipment, the name and post-office address of each person participating or assisting in the operation other than the licensee, and such other information as may be required by the department, and shall report the same to the department immediately upon the completion of each operation.

412. Each licensee shall further prepare and maintain an evaluation statement for each operation which shall include a report as to estimated precipitation, defining the gain or loss occurring from nucleation activities, together with supporting data therefor. This statement, together with such other pertinent information as the department may require, shall be sent to the department upon request by the department.

413. Notwithstanding any provision of this chapter to the contrary, the department may grant a licensee permission to undertake an emergency nucleation project, without compliance by the licensee with the provisions of Sections 407 to 410, inclusive, if the same appears to the department to be necessary or desirable in aid of extinguishment of fires.

413.5. Notwithstanding any provision of this chapter to the contrary, upon request of the board of supervisors of a county or of the governing body of a city or a public district of the State, and upon the submission of such supporting evidence as the department may require, the department may grant a licensee permission to undertake a nucleation project for the purpose of alleviating a drought emergency, without prior compliance by the licensee with the provisions of Section 407 requiring publication of notice of intention, if such project appears to the department to be necessary or desirable. Nothing contained in this section shall be construed as to relieve the licensee in such case from compliance with the provisions of Sections 407 to 410, inclusive, requiring publication of notice of intention and filing of proof of such publication, as soon after the granting of permission by the department as is practicable.
(Added by Stats. 1955, Ch. 1399)

414. Any license may be revoked or suspended if the department finds, after due notice to the licensee and a hearing thereon, that the licensee has failed or refused to comply with any provisions of this chapter. The proceedings herein referred to shall be conducted in accordance with the provisions of the Administrative Procedure Act, Chapter 5, Part 1, Division 3, Title 2 of the Government Code and the department shall have all the powers granted therein.

415. Any person who violates any provision of this chapter is guilty of a misdemeanor.

SECTION 6063 OF THE GOVERNMENT CODE

6063. Publication of notice pursuant to this section shall be once a week for three successive weeks. Three publications in a newspaper regularly published once a week or oftener, with at least five days intervening between the respective publication dates not counting such publication dates, are sufficient. The period of notice commences upon the first day of publication and terminates at the end of the twenty-first day, including therein the first day.

(Added by Stats. 1949, Ch. 1587; as amended by Stats. 1957, Ch. 1670, and by Stats. 1959, Ch. 954)

APPENDIX B

FEDERAL REGULATIONS PERTAINING TO WEATHER MODIFICATION

Title 45—PUBLIC WELFARE

Chapter VI—National Science Foundation

FEDERAL REGISTER, VOL. 30, NO. 250—WEDNESDAY, DECEMBER 29, 1965

PART 635—KEEPING OF RECORDS AND FURNISHING OF REPORTS IN CONNECTION WITH WEATHER MODIFICATION ACTIVITIES

AUTHORITY: The provisions of this Part 635 issued under 72 Stat. 353 and sec. 11(a), 64 Stat. 149, 153.

§ 635.1 Purpose.

The purpose of this part is to develop information for use in carrying out the responsibility of the National Science Foundation to support a program of study, research and evaluation in the field of weather modification as authorized by the National Science Foundation Act of 1950, as amended. Section 14(f) of the Act authorizes the Director of the Foundation to obtain, by regulation, subpoena, or otherwise, such information in the form of testimony, books, records, or other writings, to require the keeping of or furnishing such reports and records, and to make such inspections of the books, records, and other writings and premises or property of any person or persons as may be deemed necessary or appropriate by him to carry out this responsibility, where adequate and authoritative data is not available from any Federal agency. The information required under this regulation is not so available and therefore must be obtained from individuals and organizations engaged in weather modification activities.

§ 635.2 Application of part.

This part applies to any person, and to any organization, whether commercial or nonprofit, engaged in or intending to engage in, any weather modification activity (including research) intended to modify the atmosphere through artificial means. Such activities include, but are not limited to, any of the following:

(a) Intentional seeding of clouds and fog to alter drop size distribution, produce ice crystals, produce coagulation of droplets, or in any way to influence the natural development cycle of the cloud or its environment by dispersing into it any material or gas such as silver iodide, lead iodide, carbon black, dry ice, ammonia, etc.

(b) Intentional initiation of large heat sources or fires to influence convective circulation or evaporate fog.

(c) Intentional modification of solar radiation exchange of the earth or clouds through the release of gases, dusts, liquids, or aerosols into the atmosphere.

(d) Intentional modification of the energy transfer characteristics of the earth's land or water surface by dusting with powders, liquid sprays, or dyes.

(e) Intentional release of electrically charged particles, radioactive particles or ions into the atmosphere to alter its electrical field pattern or produce localized electrical field anomalies.

(f) Intentional application of shock waves, sonic energy sources, or other explosive or acoustic sources to the atmosphere to influence cloud growth, dissipation, or precipitation patterns.

§ 635.3 Reporting requirements.

(a) *Prior notice.* Each individual or organization intending to engage in any weather modification activity on or after February 1, 1966, shall give not less than 30 days advance notice to the Foundation of intention to engage in such activity. Such notice will be submitted on a Foundation report form, copies of which will be made available upon request from the National Science Foundation, Washington, D.C., 20550. Where intention to engage in a weather modification activity develops less than 30 days prior to the planned activity, the required report shall immediately be forwarded to the Foundation by airmail and shall be accompanied by a statement explaining why the 30-day requirement could not be met.

(b) *Activity reports.* After the weather modification activity reported pursuant to § 635.3(a) of this section has commenced, each person or organization engaged in such activity shall submit to the Foundation an activity report on field operations on a quarterly basis. This report will be submitted on the form referred to in § 635.3(a) of this section.

§ 635.4 Maintenance of logs.

Each individual or organization engaging in a weather modification activity shall maintain a daily log of such activity. The log shall contain all relevant facts, including the following:

(a) Daily Log of Ground Weather Modification Activities (including Seeding Releases):

(1) When readily available to project personnel during observational period, description of meteorological situation in target area and control area such as types of clouds, percent cloud cover, temperature, humidity, appearance of lightning, hail, funnel clouds, severe rain, snow and unusual radar patterns should be recorded.

(2) Quantitative measurements of precipitation obtained from nonfederally operated sources such as rain gauges, snow pillows, radar, optical transmissometers and streamflow gauges, in target and control areas.

(3) Any pertinent remarks on unusual results or significant events in the progress of the project should be entered in the log if they would contribute significantly to the technical evaluation of the project.

(4) In the case of the operation of a ground silver iodide generator or other dispenser of particles, aerosols or gases, the daily log shall include:

(i) Location of each weather modification device or generator in use.

(ii) Name of individual responsible for turning each weather modification device or generator on or off.

(iii) Time each weather modification device or generator was turned on and turned off.

(iv) Basis or criteria for turning on or off each weather modification device or generator.

(v) Type of material dispersed by each weather modification device or generator.

(vi) Rate of material release of each weather modification device or generator during operation.

(vii) Total material released by each weather modification device or generator during each operational period.

(b) Daily Log of Airborne or Mobile Weather Modification Activities (including Seeding Releases):

(1) Complete log of each aircraft flight or mobile generator run including, but not necessarily limited to, ground track, altitude, air speed, times over check points, release points of seeding or other charges, temperature, average wind direction and speed at release altitude, and, for aircraft, specify type of aircraft, airport or airports used and names of crew members.

(2) All other pertinent information as listed above for ground weather modification activities.

§ 635.5 Retention of records.

Records required to be maintained by this part, including logs, shall be available for inspection upon request of the National Science Foundation for a period of not less than 5 years after the date of entry. Such records shall not be required to be produced at any place other than the place where normally kept, provided a true copy of such record is made available to the Foundation, as may be requested, or there is agreement as to the information contained therein.

§ 635.6 Disclosure of information.

Information developed as a result of the reporting procedures set forth herein shall be made publicly available on a periodic basis by the Foundation. This information will not include trade secrets or other data required to be kept confidential under section 1905 of Title 18 of the United States Code, except where the Director of the Foundation determines that the withholding of such information would be contrary to the purposes of sections 3(a)(9) and 14 of the National Science Foundation Act of 1950, as amended. Individuals and organizations reporting weather modification activities may request that information which they consider to be included within the scope of 18 U.S.C. 1905 be withheld from public disclosure and the Foundation will give due consideration to granting such requests.

§ 635.7 Penalty.

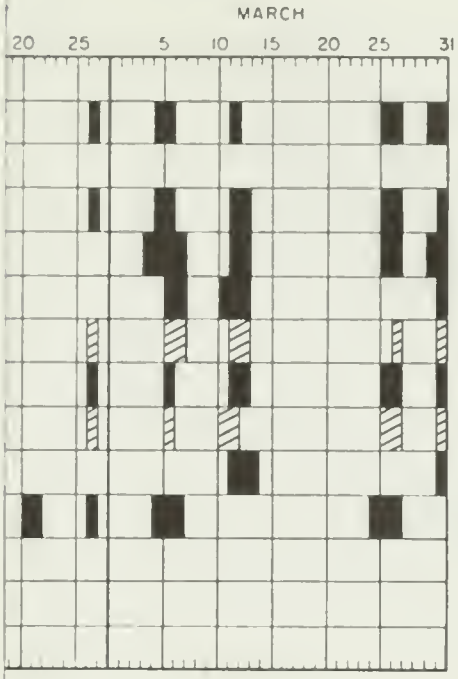
Any person willfully failing to meet the requirements imposed by this regulation shall, upon conviction, be fined not more than $500.

Effective date. This part shall become effective on January 1, 1966.

Dated: December 21, 1965.

LELAND J. HAWORTH,
Director,
National Science Foundation.

[F.R. Doc. 65-13870; Filed, Dec. 28, 1965; 8:48 a.m.]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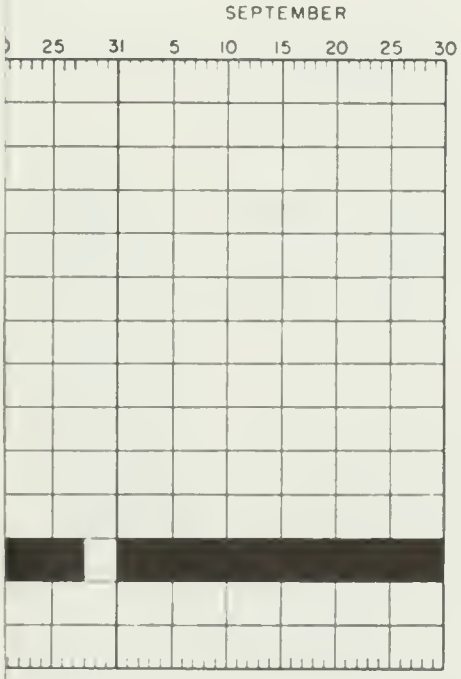
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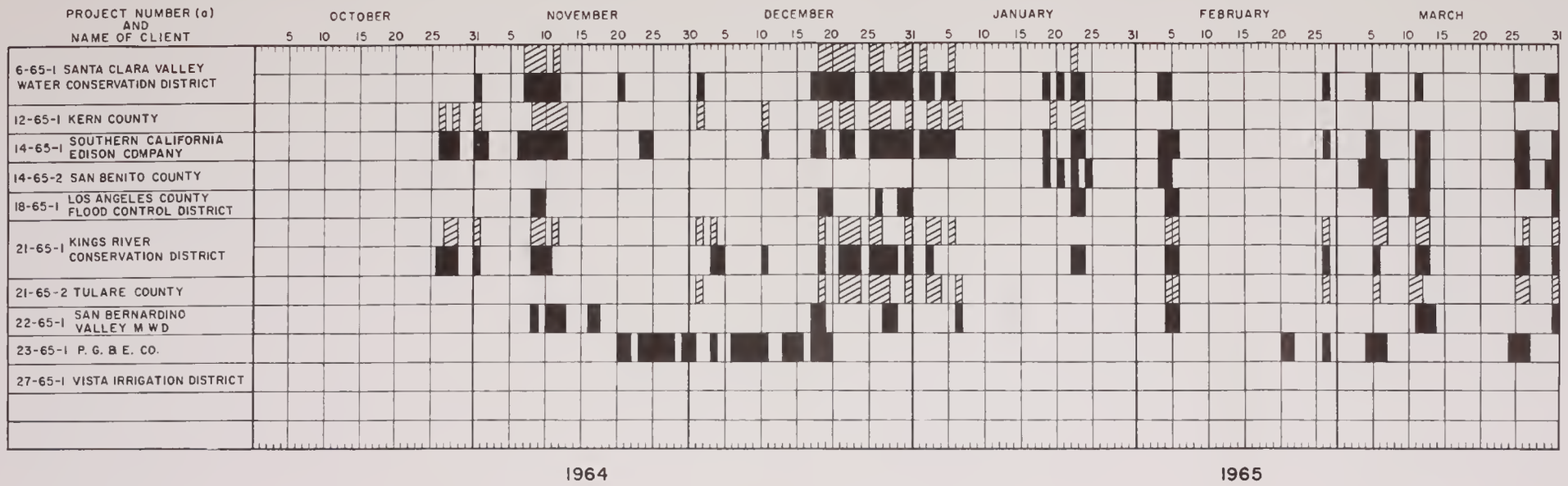

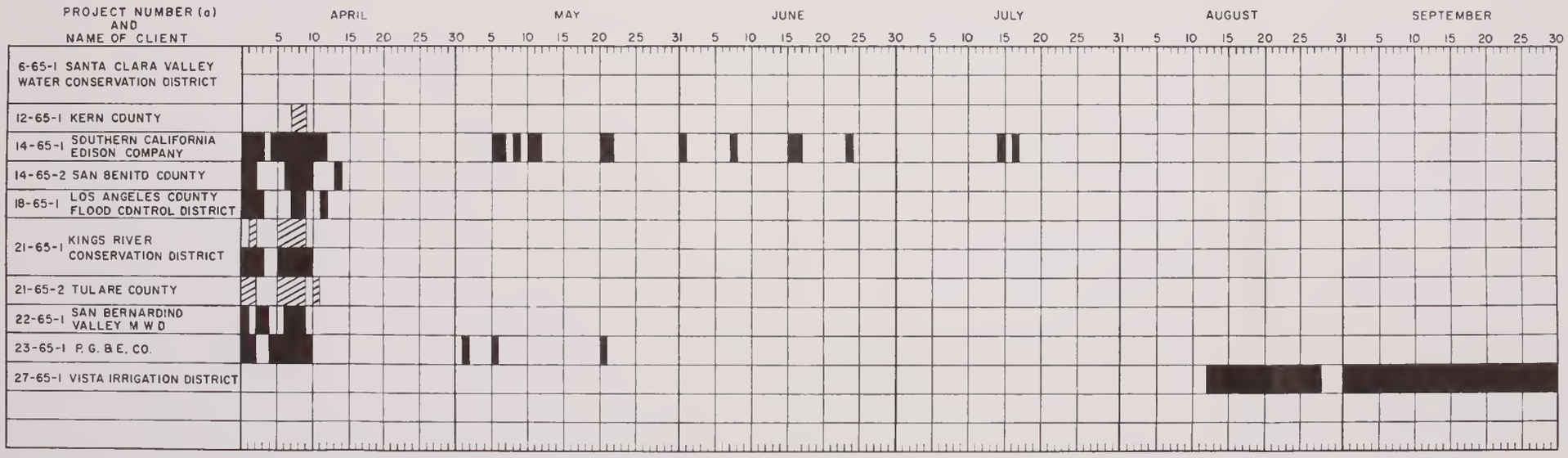

(a) Project number consists of three parts: first part indicates licensee number, second – the water year; and third – numerical sequence of projects undertaken by a licensee.

AIRCRAFT

GROUND BASED GENERATORS

WEATHER MODIFICATION OPERATIONS IN CALIFORNIA

DAYS OF CLOUD SEEDING

OCTOBER 1964 THROUGH SEPTEMBER 1965

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